

## New Claims

I Claim:

Claim (N)

An improved Sensor for at least one of measuring or controlling,  
having an output V responsive to a physical quantity I, and also  
responsive to an undesired interference N,  
the ratio of  
the said responsiveness of the said output V to said physical quantity I  
in relation to  
the said responsiveness of said output V to said interference N  
being defined as the Sensor's signal to noise ratio SNR,  
which can be stated in symbolic form:

$$SNR = \frac{\delta V / \delta I}{\delta V / \delta N}, \text{ where}$$

$\delta V$  is a change in said output V,

$\delta I$  is a change in said physical quantity I, and

$\delta N$  is a change in said interference N; and also

said Sensor is at least one of found or constructed to have the Essential Characteristic that the  
said signal to noise ratio SNR is

substantially altered by Selective Modulation of an Operating Parameter Q, and

means enabling said Sensor to function in at least one of:

as a part of Machine, or

independently.

D

1. A machine having a machine output  $V_c$  for at least one of measuring or controlling a physical quantity  $I$ ,  
 including a sensor having an output  $V$  responsive to said physical quantity  $I$ ,  
 and also responsive to an undesired interference  $N$ ,  
 the ratio of the said responsiveness of the said output  $V$  to said physical quantity  $I$   
 in relation to  
 the said responsiveness of said output  $V$  to said interference  $N$  being  
 defined as the sensor's signal to noise ratio SNR, which can be restated in symbolic form:

$$SNR \equiv \frac{\frac{\delta V}{\delta I}}{\frac{\delta V}{\delta N}}$$

where  $\delta V$  is a change in said output  $V$ ;

$\delta I$  is a change in said physical quantity  $I$ ;

$\delta N$  is a change in said interference  $N$ ; and

also said sensor is at least one of found or constructed to have the essential characteristic that the said signal to noise ratio SNR is substantially altered by Selective Modulation of an Operating Parameter  $Q$ ; and also

including means enabling the operations of at least one of said sensor and said Operating Parameter  $Q$  so that

said machine output  $V_c$  is more useful

as judged by at least one of the characteristics of said machine, including but not limited to:

- accuracy,
- sensitivity or
- speed of response
- per unit,
- dollar cost,
- power consumption,
- volume, or
- weight.

IIIN) An improved machine having a machine output  $V_c$  for at least one of measuring or controlling a physical quantity I,

- including a sensor having an output V responsive to said physical quantity I,
- and also responsive to an undesired interference N,
- the ratio of the said responsiveness of the said output V to said physical quantity I in relation to
- the said responsiveness of said output V to said interference N being
- defined as the sensor's signal to noise ratio, which can be restated in symbolic form:

$$SNR = \frac{\delta V / \delta I}{\delta V / \delta N}$$

where:

$\delta V$  is a change in said output V;

$\delta I$  is a change in said physical quantity I;

$\delta N$  is a change in said interference N; and

also said sensor is at least one of found or constructed to have the Essential Characteristic that the said signal to noise ratio SNR is substantially altered by Selective Modulation of an Operating Parameter Q;

and also including means whereby said output V of said sensor in a higher said SNR state due to a condition of said Operating Parameter Q

is combined with said output V of said sensor in a lower said SNR state due to a different said condition of said Operating Parameter Q,

and also including means enabling at least one of said sensor and said operating parameter Q and said combined so that

the said interference N is mostly removed from said machine output  $V_c$  but

said machine output  $V_c$  has a good said responsiveness to said physical quantity I, so that said machine output  $V_c$  is more useful as judged by at least one of the characteristics of said machine, including at least one of but not limited to:

- accuracy,
- sensitivity or
- speed of response
- per unit,
- dollar cost,

3/19/97

~~power consumption,  
volume or  
weight.~~

D

3/19/97

IVN) A process for constructing an improved machine having a machine output  $V_c$  for at least one of measuring or controlling a physical quantity I by canceling out an error in said machine output  $V_c$  due to an interfering noise N so as to provide an error corrected machine output  $V_c$  which is sensitive to said physical quantity I, which includes at least the steps: find/construct, and provide; described as follows:

at least one of find or construct a sensor with an output V which has a signal to noise ratio SNR which changes substantially when the condition of an Operating Parameter Q is selectively modulated; and

provide means whereby said sensor output V in a higher said SNR state due to a condition of said Operating Parameter Q is combined with said sensor output V in a lower said SNR state due to an different said condition of said Operating Parameter Q; and

at least one of said combined, said Operating Parameter Q or said sensor are constructed so that the said error due to said noise N mostly cancels at the said machine output  $V_c$ , but said machine output  $V_c$  is well responsive to said physical quantity I.

Claim 2N

A process as claimed in claim IVN, wherein said physical quantity I and said noise N during the time duration of one full operating cycle of change of said condition of said operating parameter Q are at least one of: changed by only a small amount naturally, or are so conditioned.

Claim 3N

A process as claimed in claim IVN, wherein said sensor comprises at least one of: at least two said sensors or a composite sensor having at least two sectors, and wherein each one of said two sensors or said two sectors operates full time at a different said condition of said operating parameter Q,

so that there is thereby no need to have a short operating cycle time and no need to condition said physical quantity I and said noise N or require that they be generally constant over said one full operating cycle.

Claim 4N

A process as claimed in Claim IVN wherein said sensor is a non-contact ammeter which incorporates at least one Hall device associated with a magnetic core SQ.

Claim 5N

A process as claimed in Claim IVN wherein said sensor is a non-contact ammeter which incorporates at least one Hall device associated with a magnetic core SQ, and

wherein said operating parameter Q is the magnetic reluctance of said magnetic core SQ.

Claim 6N

A process as claimed in claim IVN wherein said sensor is a non-contact ammeter which incorporates a Swain type sense coupling winding  $N_s$  wound on a core SQ.

Claim 7N

A process as claimed in claim IVN wherein said sensor is a non-contact ammeter which incorporates a Swain type sense coupling winding  $N_s$  on a core SQ, and wherein said operating parameter Q is at least one of the peak current  $I_{sm}$  or the number of turns in said sense coupling winding  $N_s$ .

## Claim 8N

An improved machine as claimed in claim IIIN, wherein:

said physical quantity I and said interference N are required to be inherently or conditioned to be largely constant in magnitude and direction for a time duration here called  $T_{A+B}$ ,

said sensor is at least one of chosen or constructed so that it has the essential characteristic that when the condition of said operating parameter Q is changed by a selective modulator, the sensitivity of said output V to said signal I is altered substantially differently from the sensitivity of said output V to said noise N in a manner called selective modulation;

more particularly, in said sensor said output V change per unit physical quantity I change is here called gain g, i.e.,

$$g = \frac{\delta V}{\delta I}, \text{ and}$$

said output V change per unit said interference change is here called noise sensitivity  $\Psi$ ,

defined as the change in said output V per unit change in said interference N, all divided by said gain, i.e.,

$$\Psi = \frac{\delta V / \delta N}{g}, \text{ and}$$

said operating parameter Q has at least two conditions here called  $M_A$  and  $M_B$  which are provided by means enabling, and

a timing means is provided with at least two states  $\textcircled{A}$  and  $\textcircled{B}$  having a total cycle time equal to or less than said  $T_{A+B}$ , and arranged to coordinate the action of said modulator,

means are provided whereby said output V is available as output  $V_A$  when in said condition  $M_A$  in said state  $\textcircled{A}$  and also said output is available as output  $V_B$  when in said condition  $M_B$  in said state  $\textcircled{B}$ ,

said means combined are constructed so as to combine said output  $V_A$  and said output  $V_B$  so that said interference N is largely canceled at said machine output  $V_c$ , and said machine output  $V_c$  has a good said responsiveness to said physical quantity I,

at least one of said means for combining and said selective modulator and said Operating Parameter Q constructed to accomplish much the same result as the following example:

said means are constructed for dividing said output  $V_A$  by divisor factor here called  $\eta$ , and

said means are constructed for subtracting said  $V_A$  divided by said  $\eta$  from said  $V_B$  to form a difference, which is the error corrected difference  $V_c$ , which becomes the said machine output  $V_c$ ,

also, during said state (A) said gain  $g$  has the value  $g_A$ , and said noise sensitivity  $\Psi$  has the value  $\Psi_A$ ; and further, during state (B) said gain  $g$  has the value  $g_B$ , and said noise sensitivity  $\Psi$  has the value  $\Psi_B$ ;

the ratio of said  $g_B$  divided by said  $g_A$  is called  $G$ , i.e.,

$$G = \frac{g_B}{g_A},$$

and we herein use the symbol  $\beta$  for the ratio of said  $\Psi_B$  to said  $\Psi_A$ , i.e.,

$$\beta = \frac{\Psi_B}{\Psi_A}, \text{ and}$$

for best results we at least one of choose or construct said sensor and build said selective modulator conditions  $M_A$  and  $M_B$  so that said sensor has the essential characteristic that said noise sensitivity ratio  $\beta$  is substantially less than said gain ratio  $G$ , i.e.,

$$\beta \ll G;$$

where an example of a practical case is

$$\beta = \frac{1}{2}, \text{ and}$$

$$G = 1.04, \text{ and}$$

where said factor  $\eta$  is the ratio of said  $V_A$  before said division to that after said division, and

wherein said factor  $\eta$  preferably has a value close to  $\frac{1}{\beta}$  i.e.

$$\eta\beta = 1; \text{ approximately, and}$$

said difference  $V_c$  comprising a reduced but still useful component of said physical quantity  $I$  but much less of said interference  $N$  because the said  $N$  in said  $V_B$  was largely canceled by subtracting said  $\frac{1}{\eta}$  part of said  $N$  in said  $V_A$ ,

so said difference  $V_c$  is what is wanted; a said machine output  $V_c$  responsive to said physical quantity  $I$  but with said interference  $N$  largely canceled.

Claim 9N

A machine with a sensor as claimed in claim 8 wherein said sensor is a non-contact current sensor.



## Claim 10N

A process for correcting an error due to an interfering noise N in the output  $V_c$  of a machine for at least one of measuring or controlling a physical quantity I which is at least one of an electric current, temperature, pressure, etc., by the process here called selective modulation, including but not limited to the steps of providing a sensor having an output V and at least one of choosing or manufacturing said sensor so that it has the essential characteristic defined in the following terms:

said sensor output V changes in response to a change in said desired physical quantity I and has a gain g which is defined as the ratio of said change in V divided by said change in I, i.e.,

$$g = \frac{\delta V}{\delta I},$$

where said  $\delta V$  represents a partial derivative i.e., a small change in said output V produced by a small change in said I represented by said  $\delta I$ , it being understood that all other variables are held constant, and also

said output V also changes when there is a change in said noise N, i.e., said output V has a sensitivity to said noise N, here called  $\Psi$  and defined so that it is referenced to an equivalent of said input I by said gain g, i.e.,

$$\Psi = \frac{\delta V / \delta N}{g}$$

and wherein the signal to noise ratio SNR of said sensor is the inverse of said  $\Psi$ , i.e.,  $SNR = \frac{1}{\Psi}$ ,

together with the step of at least one of choosing or manufacturing said sensor so that it has an operating parameter here called Q, the condition of which, when altered by selective modulation M, substantially modifies the value of said signal to noise ratio SNR, and

said process includes at least one of the steps of finding or constructing said sensor having said essential characteristic within the bounds of at least one of practical values or conditions of said selective modulation M so that said error correction is useful, an example being;

said M has values  $M_A = 20$  and  $M_B = 50$

said g has values  $g_A = 10$  and  $g_B = 11$

said  $\Psi$  has values  $\Psi_A = 35$  and  $\Psi_B = 14$

Then the ratios of said values are:

$$\frac{M_B}{M_A} = \frac{50}{20}, \quad \frac{g_B}{g_A} = \frac{11}{10}, \quad \frac{\Psi_B}{\Psi_A} = \frac{14}{35},$$

$$= 2.5, \quad = 1.1, \quad = 0.4,$$

Said  $\frac{\Psi_B}{\Psi_A} = 0.4$  has been found to be useful and practical, and

the said process also involves combining, by at least one of, but not limited to, the steps of subtracting the said output when said selective modulation M has at least one of one or several values in a first range, all divided by a divisor factor here called  $\eta$ , from the said output when said M has at least one of said values in a second range;

where for said error correction the value of said  $\eta$  is preferably close to said  $\Psi_A$  divided by said  $\Psi_B$ , as in the above example, but the value of  $\eta$  is adjusted for best said error correction,

$$\eta = \frac{\Psi_A}{\Psi_B}, \text{ approximately,}$$

$$= \frac{35}{14}$$

$$= 2.5; \text{ and}$$

the result of said combining which may be said subtracting is the desired said error corrected output  $V_c$  of said machine; and at least one of the steps of: obtaining or conditioning: obtaining the result of said combining as computed during a time when both said physical quantity I and said noise N are essentially constant; or conditioning both said I and said N so that they are at least one of held essentially constant during said combining; or said combining is done continuously, with practically no limitation on the duration of said time during which said signal and said noise are constant; and in the said step of said continuous combining using two said sensors; here called sensor A and sensor B, with outputs  $V_A$  and  $V_B$ , - used simultaneously with the said operating parameters Q set to operate said continuously at different conditions said  $M_A$  and  $M_B$  so that said sensor A has said  $SNR_A$ , and said sensor B has said  $SNR_B$ , and when said combining is said  $V_A$  divided by said  $\eta$ , and said result of said subtracting  $V_c$  is made continuously available as said error corrected machine output  $V_c$ .

Claim 11N

A process as claimed in claim 10 wherein said sensor is a non-contact current sensor.

## Claim 12N

A process for constructing and using a sensor with reduced error for at least one of measurement or control including means:

a core of low magnetic reluctance material, here called  $S_Q$ ,

a coupling sense winding on said core having a number of turns, here called  $N_s$ ,

an inverter having an output current, here called  $i_s$ , and an average said output current here called  $I_s$ , and also constructed such that said inverter has an operating parameter which is the peak value in either direction of said current, here called  $I_{sm}$ ,

a low input impedance means converting the said average value  $I_s$  of said inverter current to an output voltage here called  $V_c$ ,

and said process includes:

positioning said core so that it is influenced by a conductor carrying a signal current  $I$  to be measured,

said position being within the effective range of a magnetic field noise, here called  $N$ , causing at least part of an error in the form of a change in zero offset of said output voltage  $V_c$ , wherein the sensitivity of said  $V_c$  to said noise  $N$  is here called  $\Psi$ , and defined as the change in said  $V_c$  due to a unit change in said noise  $N$  divided by a gain  $g$ , i.e.,

$$\Psi = \frac{\delta V_c}{\delta N} \cdot g, \text{ where}$$

said  $g$  is defined as the change in said output  $V_c$  due to a unit change in said signal current  $I$ ; i.e.,

$$g = \frac{\delta V_c}{\delta I}, \text{ and}$$

said process also includes series connecting said  $N_s$ , said inverter, and said low input impedance means converting;

and constructing said means, including at least one of: said  $N_s$  and said  $I_{sm}$ , so that the change in said gain  $g$  is considerably less than the change in said noise sensitivity  $\Psi$ , as said noise sensitivity  $\Psi$  is reduced from a maximum to a value considerably less than said maximum, said reduced being accomplished by altering the value of said means, including at least one of the number of turns  $N_s$

on said winding or the said peak inverter current  $I_{sm}$ , said altering being preferably in the direction of a greater value of the product of said  $N_s$  and said  $I_{sm}$ ,

and operating said sensor with said product of said  $N_s$  and said  $I_{sm}$  set so that said noise sensitivity  $\Psi$  is considerably reduced below said maximum,

thereby constructing and operating said sensor with said reduced error in zero offset due to said noise  $N$ .

#### Claim 13N

A Swain Meter type non-contact direct current ammeter sensor with improved accuracy for at least one of: measurement or control, which comprises:

a core, here called SQ, of low magnetic reluctance material,

a coupling sense winding, here called  $N_s$ , on said core SQ,

an inverter with power supply, here called X, with output terminals having a current  $i_s$  flowing which has an average value  $I_s$ , and also a peak value  $I_{sm}$  which is an operating parameter Q, all of said currents capable of flowing in either direction in said output terminals,

a low input impedance means converting said average current  $I_s$  to an average output voltage V,

a current carrying conductor carrying a signal input current I, which is to be at least one of: measured or controlled; positioned so that said current I influences said core SQ, and

said core SQ is within the effective range of an interfering magnetic field noise, here called N, and

said coupling sense winding  $N_s$  series connected with said output terminals of said inverter X and said low input impedance means converting,

said operating parameter  $I_{sm}$  set to a greater magnitude than the magnitude corresponding to the minimum signal to noise ratio, here called SNR, so that thereby the said SNR is considerably increased over said minimum, so that said non-contact ammeter has considerably greater accuracy in the presence of said interfering magnetic field noise N.